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November 17, 1987

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Federal Communications Commission
Office of the Secretary
1919 M Street N.W. Room 222
Washington, D.C. 20554

RE: MM Docket No. 87-268

Dear Commissioners:

Please find enclosed one original plus nine copies of NYIT's response to the Commission's Notice of Inquiry. We would like to thank the Commission for this opportunity.

Respectfully submitted:

William E. Glenn

William E. Glenn
Director

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Before the

Federal Communication Commission
Washington, DC 20554

In the matter of Advanced Television System and Their Impact on the Existing Television Broadcast Service	))))	MM Docket No. 87-268 RM - 5811

Comments of the

New York Institute of Technology
Science and Technology Research Center

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William E. Glenn, Ph.D.
Director

November 18, 1987

Before the
Federal Communications Commission
Washington DC 20554

In the Matter of	)	
Advanced Television Systems and Their Impact on the Existing Television Broadcast Service	)	MM Docket No. 87-268
Review of Technical and Operational Requirements Part 73-E, Television Broadcast Station	)	RM-5811
Reevaluation of the UHF Television Channel and Distance Separation Requirements of Part 73 of the Commission Ruler	)	

Comments of the
New York Institute of Technology

The New York Institute of Technology ("NYIT"),[1] submits the following comments in response to the Commission's Notice of Inquiry ("Notice") released in the above captioned matter on August 20, 1987. We believe the issues presented by the Notice carry long-item consequences for the future of television in the United States. NYIT urges the Commission to support the compatible Advanced Television (ATV) system being developed by

1. NYIT is a not-for-profit educational and research institute having a Science and Technology of Research Center, Dania, Florida. The director of the STRC, is Dr. William E. Glenn. The Center's primary activity is advanced television research and development.

Dr. William Glenn and his group at NYIT's Science and Technology Research Center.

I. Introduction and Summary of NYIT Position

The Notice addresses the many issues involved in formulating adoption of advanced television (ATV) standards or recommendations for the broadcast industry. It is important that the Commission evaluate and support the overall needs of the U.S. public and the U.S. television broadcast industry and not let off-shore technology establish de-facto standards that do not meet these needs. NYIT agrees that the NTSC standard has been flexible and has served the American public well for almost 50 years. It is our belief that with the established base of NTSC broadcast equipment and more than 130 million receivers in U.S. households, any ATV system must be fully compatible with the NTSC standard. NYIT also urges the Commission to support an ATV system that provides all of the advantages of High Definition Television (HDTV) [2] wide aspect ratio. Over 800 TV lines of resolution, color fidelity, improved audio etc.). It is expected that any new broadcast system must co-exist with NTSC for many years and be of sufficient quality and adaptability to support ATV broadcasts for the next 50 years.

2. HDTV is defined as a television system which provides resolution vertically and horizontally that exceeds twice the resolution of 525-line images as measured on a test chart.

For economic reasons, an ATV system must be also compatible, with all of the various broadcast modalitites; terrestrial, cable, satellite and fiber optics. It is also in the economic interest of the general public that the standard be adaptable or compatible with other program distribuiton media such as video tape recorders (VCR's) and video disk. The NYIT system[3] satisfies all these criteria, and therefore must be strongly considered.

The Notice also seeks recommendations on spectrum allocations related to the terrestrial broadcasters' distribution of ATV. Any ATV broadcast system which provides for a full High Definition image, and audio distribution will require additional bandwidth over and above the present 6 MHz channels. An augmentation channel, either in UHF or VHF bands, should be reserved to allow all TV licensees the opportunity to provide improved service and to insure the competitiveness of local television service.

Time is of the essence. HDTV technology is advancing rapidly and is being introduced into the television and motion picture production processes. National distribuiton of HDTV in Japan by NHK, using satellite broadcast, in an incompatible HDTV format called "MUSE" is planned for 1990. Distribution of prerecorded program material for VCRs is also

3. The NYIT system is a bandwidth-reduced ATV transmission system for NTSC-compatible HDTV transmission. The system is referred to interchangably as the NYIT system or the Glenn system.

planned for both Japan and the U.S.. Unless U.S. terrestrial broadcasters have a viable means of distributing HDTV, in the very near future, they will become non-competitive and relegated to a second-class distribution media. This is not in the public's interest. Therefore any potential ATV distribution system must be compatible with HDTV, must be based on sound technological principles, and must allow for subsequent improvement. Improved, or enhanced NTSC [4] systems will not be able to compete in the long term with HDTV. The NYIT system provides for improved NTSC transmission, is compatible with HDTV, is based on years of psychophysical research, and is in advanced development.

II. The NYIT (Glenn) System

For the past seven (7) years, the Science and Technology Research Center of the New York Institute of Technology has had a major project devoted to the development of a NTSC - Compatible high definition television (HDTV) transmission system. The thrust of this program has been to allow terrestrial broadcasters to augment existing NTSC transmissions, compatibly to HDTV, by the addition of a "detail" augmentation signal in existing unused television channels. This system has been designed to equal or

4. Improved or enhanced NTSC is defined as systems which transmit information in an 525-line format and are compatible with NTSC transmission. Improved systems provide better performance within the 6 MHz spectrum and enhanced systems require more spectrum.

exceed the performance of the HDTV system being developed in Japan.

It is interesting to note, that in the Notice of Inquiry, the discussions of the limitations of current NTSC systems all pertain to defects reflecting visual psychophysical parameters. This is exactly why scientists at NYIT have relied so heavily on visual psychophysical measurements to guide the design and development of the HDTV transmission system. Information derived from these measurements, as well as that from other laboratories, has been used to formulate the system configuration and to select the signal processing parameters. The purpose of these studies is to evaluate what information can be deleted from the transmission without reducing resolution and picture quality, and without introducing artifacts that can be detected by the human observer. Most of the measurements are intended to determine the threshold of perception for a property of an image. Using these data, systems can be designed so that potential artifacts that exist in the image are below the threshold of perception and therefore cannot be seen by the observer. Results of these measurements have been published and presented, at several nationaland internationaltechnical symposia. Included as Appendices to this submission are several papers describing both the NYIT system in detail and the supporting psychophysical vision data.

As the NYIT system has been designed to be compatible with standard NTSC receivers, it has been necessary to consider the issues listed as "Limitations of the Current NTSC System" in the Notice of Inquiry paragraphs 8 thru 17. The NYIT ATV system design provides solutions to problems of interline flicker, line crawl, vertical aliasing, static temporal aliasing, cross-color, cross-luminance and compressed aspect ratio. Rather than degrading the present televised image, the NYIT-recommended changes in the basic NTSC transmission will actually slightly improve the image on unmodified receivers. The NYIT format for HDTV transmission incorporates many of the principles also recommended by other ATV proponents in their proposals for enhanced NTSC television.

Many producers are currently recording program material in an 1125-line HDTV production format. We have therefore proposed a transmission format that is intended to accept 1125-line program material, and an HDTV receiver design intended to display information in an 1125-line format.

While the NYIT system is intended to accept 1125-line production program material, it has incorporated in the design an opportunity for further improving the resolution of the HDTV image, by the use of progressive scan both in the originating HDTV camera and in the HDTV display. If progressive scan is used, the resolution will exceed that of MUSE and that of broad-band 1125-line interlaced cameras and displays.

Given the Japanese timetable for the introduction of HDTV into the market, it is necessary for terrestrial broadcasters to provide full HDTV service as soon as possible, if they are to compete for viewers with other methods of video distribution. Once viewers have become accustomed to the sharpness of large HDTV images, broadcasters will not have the luxury of providing only improved or enhanced TV service. The NYIT system has been designed to provide the broadcaster an opportunity to upgrade their system to HDTV at minimum cost, and with minimum disruption to the standard operation of television stations.

III. Comparison of ATV Approaches

NYIT agrees that there are techniques available with today's technology that can improve present NTSC video and audio transmissions. These improvements should be strongly considered by the Commission for incorporation into new stadards. This is particularly true for any planned standards that maintain NTSC compatibility and are also compatible with ATV systems that have HDTV capability.

The approaches addressed in the Notice of Inquiry can be classified into three broad catagories namely:

A. Improved NTSC
B. Enhanced NTSC
C. HDTV

In discussing improved NTSC, enhanced NTSC, and HDTV, it is important to understand the viewing conditions and purposes of each. Studies of visual psychophysics indicate that for optimum viewing, the limiting resolution of the displayed image should be about 22 cycles per degree of visual angle, on the viewer's retina. This means that present NTSC television should be viewed at 7 screen heights, enhanced television at about 5 screen heights and HDTV at 2.5 to 3 screen heights. HDTV has been designed to provide both sharpness and wide field-of-view comparable to that of 35mm projected motion-picture film.

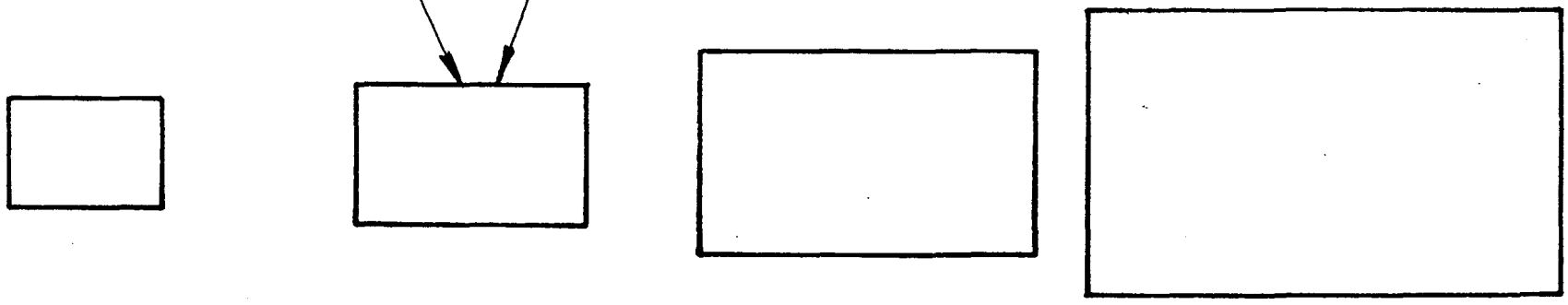
For the average home, viewing is typically at six to ten feet. In a room that now uses a 19" television display, (typical NTSC) equal sharpness will be provided by an enhanced receiver with a 26" display, and an HDTV receiver with a 50" display. The higher price of an HDTV set results primarily from the use of a larger display, rather than from more complex signal processing. We expect that HDTV and enhanced receivers will co-exist in many households with one HDTV display for primary viewing, and smaller less expensive, enhanced NTSC receivers used in other locations within the home. Table I. provides a comparison of four systems with NTSC. The retangles indicate the relative display size of these sytems at the same sharpness when viewed at the same distance.

It is essential that to remain competitive present transmission be augmented to provide full HDTV resolution. If

TRANSMISSION SYSTEMS

	NTSC 1 channel	PHILIPS Compatible 2 Channel	RCA Compatible 1 Channel	MUSE Incompatible 2 Channel (Adjacent)	NYIT Compatible 1½ Channel (Non Adjacent)
V Res	350	450	450	750	920
H Res	350	350	450	600	920
Video Bandwidth	4.2	8.4	4.2	8.1	7
Field of View (Degrees)	8x11°	10x17°	10x18°	15x25°	21x35°

Relative size (Same Resolution on Viewer's Retina)



this is done, the same transmission signal can be used by enhanced NTSC receivers. In 1985, NYIT submitted a proposal to the Enhanced(T2) subcommittee of ATSC, that provides for both enhanced and HDTV receivers, using the same signal format.

A. Comments on Spectrum Management and Compatibility

The following comments are provided to the specific questions raised in the Notice of Inquiry (Page 5).

1. Evaluation Criteria

Because of the anticipated early introduction of full resolution HDTV by competitive distribution media, HDTV broadcast systems with equal or better performance than MUSE should have first priority.

It is the opinion of NYIT that this can be done within the existing television spectrum, only by using NTSC-compatible transmissions, with augmentation to HDTV in existing available spectrum in UHF and occasional VHF channels.

Video and audio should be evaluated for resolution, motion rendition, susceptibility to noise and multipath echoes, sound quality and elimination of artifacts. Priority should be given to systems that can provide both HDTV and enhanced NTSC within the existing terrestrial broadcast spectrum.

2. ATV Changes in the Near Future

Enhanced NTSC systems can be built that remove most of the existing NTSC artifacts and provide a resolution of about 450 TV lines both vertically and horizontally, and with a wider-aspect ratio display. It is our opinion that it will not be possible to provide resolutions of 700 to 900 TV lines both vertically and horizontally compatibly in a single 6 MHz channel. Even in the unlikely event that this could be done incompatibly, two channels would still be required, for a long time, since a station would be required to transmit both NTSC and HDTV, to maintain its audience. HDTV will not suddenly replace NTSC, as a large audience for NTSC transmissions now exists, and will continue to exist, in the foreseeable future.

All-digital ATV terrestrial transmission will not be possible in the near future, without discontinuing the majority of the NTSC transmissions. All-digital HDTV transmitted by fiber optic cable will be possible, but expensive. Nor will it be in the best interest of the general public, since initial installations will be in new sub-divisions and not in the major urban areas. In addition, it will be costly and discriminate against those who cannot afford the service. This option would also reduce the audience served by terrestrial broadcasters, and thereby limit the revenues available to them for providing "free"

HDTV quality service to viewers.

3. Speed of Development

The NYIT system has been under intensive development for seven years. A closed-circuit version of the concept has been publicly demonstrated at the recent 1986 and 1987 NAB conventions. At the 1987 convention, NYIT demonstrated a progressively scanned camera with a vertical and horizontal resolution in excess of 800 lines in the 1125-line format. This resolution exceeds that available from the output of interlaced 1125-line cameras. The NYIT system and the MUSE system are the only real-time HDTV bandwidth-reduced transmission systems that have been demonstrated. A new system that can be used for terrestrial transmission experiments as well as by cable and satellite, is currently nearing completion at NYIT. This is the 5th generation real-time system that has been constructed. This system provides all of the synchronizing signals in the transmitter and receiver to allow non-adjacent and non-colocated transmission of the detail augmentation signal. This signal has been designed to minimize co-channel and adjacent channel interference.

The transmitter provides improved NTSC resolution (since the detail for the NTSC signal is derived from a progressively scanned HDTV camera). Temporal enhancement in the

transmitter is used to improve motion rendition in both NTSC and HDTV images. Progressive scan at 60 frames per second is used in the display of the HDTV image in the receiver. The augmentation signal includes detail augmentation of both luminance and color.

We intend to use this prototype HDTV transmission system primarily to study terrestrial and cable propagation,and interference parameters during 1988. Using real-time transmission and receiver equipment, we expect to obtain sufficient field experience to enable us to answer most of the spectrum allocation and performance questions.

Realistically, we expect that another year will be needed in order to have a prototype operating that incorporates necessary modifications to the system that have resulted from the spectrum allocation studies and from field experience.

4. System Costs

The NYIT system has been designed to minimize the costs that the terrestrial broadcaster will incur in augmenting television transmissions to HDTV. Because of its compatibility, the system can initially utilize most of the existing installed capital equipment in a television station. The cost of the processor at the transmitter is a minor cost for upgrading. In cases where an adjacent

channel is available for augmentation, a single antenna and transmitter final amplifier may be used.

Undoubtedly, HDTV will be introduced in much the same way as was color. Until there is a large audience with HDTV sets, only a few hours a day of program material will be augmented to HDTV. These will be football games, special productions, and motion pictures. Initially a station can provide this service using a network feed and/or an HDTV tape recorder. The high capital investment of equipping studios and production facilities with HDTV equipment can be delayed until the existing equipment becomes obsolete, and HDTV has a widespread viewing audience.

For the consumer, terrestrial distribution of HDTV program material will be less costly than HDTV distributed by cable, satellite or pre-recorded media and will be widely available.

HDTV receivers are expected initially to cost slightly more than the large-screen projection displays that are now becoming popular. Market size and new technology will undoubtedly reduce this cost with time, as was the case with color television. The sale of enhanced NTSC and HDTV receivers that use the same transmission format, will allow consumers who are unable to afford large-screen displays, to benefit from many of the technical improvements at a

lower cost.

5. Augmentation Spectrum

The NYIT system does not require the augmentation signal to be adjacent in the spectrum, or to have its antenna co-located with the existing NTSC transmitter. Where an adjacent channel is available, it may allow augmentation at lower cost to the station owner.

The system can be designed to either use a 3 MHz augmentation channel or a full 6 MHz channel, time-shared between two stations. Both of these techniques require the same average spectrum. However, since the spectrum is currently allocated with 6 MHz channel widths, it may be preferable to time-share a full channel between two stations, rather than divide the frequency spectrum in half. Spectrum allocation studies will be able to answer the question as to which is preferable.

In summary, if the NYIT HDTV system is accepted, the present NTSC television channel assignments can stay where they are. Augmentation has been designed to allow for the use of spectrum that cannot now be used for standard NTSC transmissions because of interference. Augmentation need not be adjacent in frequency or co-located with the NTSC transmission. All existing stations can probably be augmented to HDTV within the existing television spectrum.

Loss of spectrum will undoubtedly limit the number of stations that can be augmented to HDTV and therefore these stations will suffer by their inability to compete for audience share as HDTV becomes more common.

IV. Comments On Spectrum Allocation Issues

The Notice of Inquiry has listed three ways of potentially providing ATV terrestrial services. NYIT strongly recommends that the commission suport, option 2 (that of augmenting wherever feasible, existing NTSC service, with no provision for full replacement of the NTSC service).

One must consider what reasons, other than compatibility, might be valid for elimination of NTSC in the foreseeable future. The existing NTSC spectrum is quite efficiently used. Improved NTSC modifications can somewhat better exploit this spectrum, and still maintain compatibility. Therefore elimination of NTSC would not produce a significant saving in spectrum. One might ask if compatibility were not an issue; could HDTV be transmitted in an existing channel? To date, no system has demonstrated full HDTV resolution within a single channel. Could eliminating NTSC reduce receiver costs? The cost of processing in the receiver to utilize NTSC efficiently is rapidly decreasing so that this is no longer a significant factor. There appear to be no advantages to eliminating NTSC in either the long or the short term. It's elimination would probably not have an appreciable impact on

spectrum requirements or on receiver cost.

One should learn from past experience in broadcasting. Although nearly 50 years have passed since NTSC was introduced, many black-and-white receivers are still being sold. Fifty years from now we expect that the same situation will be true for 8 - 19" portable NTSC receivers. Thus, there seems to be no compelling reason to eliminate NTSC in the foreseeable future.

The Commission has solicited specific comments on implementing ATV services within the VHF and UHF spectrum, under various criteria. NYIT is pleased to provide the following comments and recommendations:

NYIT believes that the Commission should implement an ATV service for both VHF and UHF in a comprehensive plan. This plan should be formulated as soon as possible so that broadcasters can make the changes necessary to maintain their competitive position.

Prior discussions herein have addressed the technical and economic advantages of this spectrum option. In summary, given this option, stations can augment to both enhanced NTSC and HDTV in a cost effective manner and with minimum disruption to their present service. In addition, it provides for efficient and maximum utilization of the available spectrum.

With regard to the question of how much additional bandwidth

could be made available and the potential interference implication, NYIT offers the following:

The NYIT system is flexible and designed to allow for changes in spectrum allocation criteria. Therefore, the NYIT HDTV augmentation signal can make use of available UHF and VHF spectrum. NYIT plans to perform extensive transmission tests on its system in 1988. These tests are expected to be performed in cooperation with ATSC and NAB. NYIT expects, as a result of these planned tests, to provide new recommended criteria that the Commision can use in relaxing co-channel, adjacent-channel, and taboo channel protection ratios for the special HDTV augmentation signal.

NYIT recommends that there should <u>not</u> be "repacking" of the UHF and VHF spectrum. Preliminary analysis suggests that new protection crieria be established which will provide adequate HDTV augmentation spectrum, without the need for repacking. Repacking would place an unnecessary burden on current station and receiver owners.

The existing protection criteria for interference between NTSC stations have been thoroughly studied, have served the industry well and appear not to need changing. There has been no study of these criteria on augmentation signals. A study should include interference between two augmentations signals, interference of a NTSC signal with an augmentation signal, and conversely. NYIT believes that this sould be done so that HDTV

augmenation signals can be designed in such a way that maximum use can be made of the existing spectrum.

NYIT has considered the possibility of providing HDTV or ATV services using microwave frequencies above 1 GHz. We offer the following comments with respect to specific questions raised in the Notice of Inquiry:

Tests to date of the potential use of non-broadcast portions of the spectrum (above 1 GHz) for HDTV or ATV are very discouraging. For economic and technical reasons, this does not appear to be a viable option.

In general, utilization of the spectrum above 1 GHz is not economically attractive because of the large number of special, directional antennas required for coverage equivalent to that which we now have at lower frequencies. The higher susceptibility to weather, physical obstruction, vegetation, and other forms of attenuation make this spctral region unsuitable for terrestrial use. In summary, NYIT agrees with the Commission that "it appears that there are promising approaches for the implementation of advanced service that utilizes frequencies already alloted for television broadcast use. Such approaches would encourage existing broadcasters to participate in the provision of such ATV service, would foster compatibility with the NTSC service and would promote more intensive use of the existing broadcast standard".

UHF Taboo Issue

In response to the Commission's request for comments on UHF taboo issues, NYIT offers the following commentary which relates specifically to NYIT's proposed HDTV system.

In the NYIT compatible HDTV transmission system, the augmentation has been designed so that it will produce minimum interference on existing receivers. This augmentation signal has its own synch and burst signal. However, the level of these signals are to be set lower than the video level, so that they will produce a significantly lower signature than the synch and burst signals of NTSC transmissions. The augmentation signal will probably use single side-band suppressed carrier transmission. Therefore it has neither a carrier, a color carrier, nor a sound carrier. The elimination of these signals further reduces potential interference. Until extensive interference tests are finished, it is not completely known what the new taboo protection requirements will be for this specialized augmenation signal. It is expected, however, that interference on existing standard sets will be considerably less than interference caused by NTSC signals.

In new HDTV receivers, there can be specifications on local oscillator radiation to protect standard receivers from interference, when HDTV sets are tuned to the augmentation channel.

Another question raised relates to the interference caused by existing NTSC stations, on a new HDTV receiver that is using augmentation in a channel formerly protected by a taboo. As these are all new receivers, using improved technologies, they will incorporate receiver modifications needed to reduce intermodulation products caused by I.F. and local oscillator radiation from standard NTSC sets. The augmentation signal only contains detail luminance and detail color. Image enhancers frequently use preemphasis and "coring" to eliminate interference by low level signals and noise. The NYIT program intends to study the use of these same techniques to "core out" noise, low level multipath echoes, adjacent and co-channel low level interference, and low level interference normally protected by taboos.

After analysis of data resulting from the planned interference tests, a new set of criteria for the specialized augmentation signals should be considered.

VII. Advanced Television Compatibility Issues

NYIT fully agrees with the Commission's findings that, "the introduction of an ATV system which is not viewable on NTSC receivers could be costly to viewers. We consider the compatibility of any new ATV system with the existing NTSC system to be an important consideration". We also agree that any

dislocation of service to the great majority of video consumers will be intolerable and not in the public interest.

In the development of the NYIT system, the NYIT system design has been consistent with the Commission's definition of NTSC compatibility. Specifically, the NYIT system is compatible with the existing television allotment plan as it operates with the present 6 MHz channelization scheme. It is also receiver-compatible, as it can be decoded and viewed on a conventional NTSC receiver.

A. Transition Issues

The NYIT transmission system is fully compatible and will provide an improvement in the quality of images displayed on a standard NTSC receiver. An HDTV receiver would also be downward compatible, without modification. In the receiver an NTSC transmission can be scan-converted to the HDTV format and include all the signal processing necessary to eliminate the NTSC artifacts (like cross-color, cross luminance, line structure, etc.) For HDTV, the detail augmentation signals for luminance and color are simply added to these NTSC signals in the same scan format. If no augmentation exists for that station it displays an improved NTSC resolution image. The HDTV set is thus automatically compatible with standard NTSC transmission.

For several reasons, it is neither desirable, nor in the public interest, to build adaptors for standard NTSC receivers to

incorporate ATV. First, the display tube of a standard receiver will normally not display higher resolution images even if higher quality signals are provided. Secondly, viewers normally select a distance for viewing that is long enough to reduce the visibility of line structure of a 525-line interlaced display. Even if the display tube could resolve higher resolution, it would be desirable to use more scanning lines for the ATV signal so that the viewer can see the higher resolution image without objectionable line structure. Very few sets could be easily modified to accommodate the higher number of scanning lines nor the wider aspect ratio of HDTV displays. Consequently, there is little advantage in trying to adapt an existing set to ATV. There is, however, considerable advantage in preserving the NTSC transmission format for use by inexpensive sets under 19". Both enhanced NTSC sets (19" to 26") and HDTV sets (40" to 60") will require higher resolution displays with scans of more than 525-lines.

NYIT does not believe that the simultaneous broadcast of incompatible ATV and NTSC transmissions is a viable solution. This would place an economic burden on the broadcaster and would certainly be very inefficient in terms of spectrum utilization, if in fact there is enough spectrum to accommodate this option.

B. Relaxation of the Mandatory NTSC Standard

Enhanced and HDTV ATV systems will undoubtedly require some modification or relaxation to the present NTSC standard. These